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AND ABSTRACT OF THE LITERATURE

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Preventive Medicine in Industry
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Moisture as an Etiologic Factor in Industrial Infections

Results of Removal of Dental Focal Infections

Masks and Respirators for Protection against Dusts and Fumes

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AN EXPERIMENTAL STUDY OF DIATHERMY*

ROBERT C. LONERGAN, M.D.

Resident Teaching Fellow, Harvard Medical School, Department of Orthopedic Surgery

From the Department of Physiology, Harvard School of Public Health, and the Department of Orthopedic Surgery, Harvard Medical School, Boston, Mass.

DURING the past few years the attention of the medical profession has been directed frequently toward electrotherapeutic measures; of these probably none has attracted more notice than the various uses of the high frequency current, especially that type which applies the d'Arsonval circuit and which is popularly known under the term "diathermy" or "diathermia." In the present medical literature one finds articles and references giving the clinical results after diathermy from a wide range of uses and modes of application; yet there seems to be a paucity of experimental work to substantiate and clarify its effects.

Previous to the World War certain foreign investigators, such as Setzu (1) (2), Schemmel, von Bernd (3), and Labbé and Blanche (4), conducted experimental work. The most interesting study was that of Setzu, who applied diathermy at 2.5 amperes to living and dead animal flesh in a series of experiments and recorded the temperature changes in the tissues. He attempted to provide a graduated scale, using dead animal flesh, flesh from a freshly killed animal, narcotized animals, and animals unnarcotized. Setzu contended that the greater the amount of life in the tissues the less was the rise in temperature—an inference which he further amplified by saying that there is a physiologic reflex which acts to impede the accumulation of heat in any localized region. In these experiments the scale of life to death was, of course, an artificial one, but the temperature data during thirty to sixty minute intervals of diathermy showed the presence of temperature

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elevation in the tissues. The figures were somewhat higher than the results which we obtained, but the amperage was also higher and, in our experience, rather above the point of the animal's endurance. In reference to anesthesia, the experimental work done by Macleod and Taylor (5) (6) proved rather conclusively that it does not affect the spread of temperature changes in animals. In the main, however, the data mentioned below agree with the conclusion reached by Setzu.

This paper records the results of a series of experiments made on subjects for the purpose of showing temperature changes after application of diathermy. It was felt that the determination of temperature changes in the tissues after the application of diathermy would provide a reliable index and basis for the judgment of its effects. Our first efforts were concerned with nonliving tissues, and these were followed by more extensive study of the temperature changes in living subjects, *i.e.*, the laboratory animal and the human being.

Apparatus[1]

For the purpose of the experiment a high frequency machine of standard make was used. It developed an average voltage of 12,000 in the d'Arsonval circuit. The current was measured by a milliammeter attached to the machine, and was applied to the surface by means of lead-tin electrode plates of different sizes, depending on the subject and on the object in view.

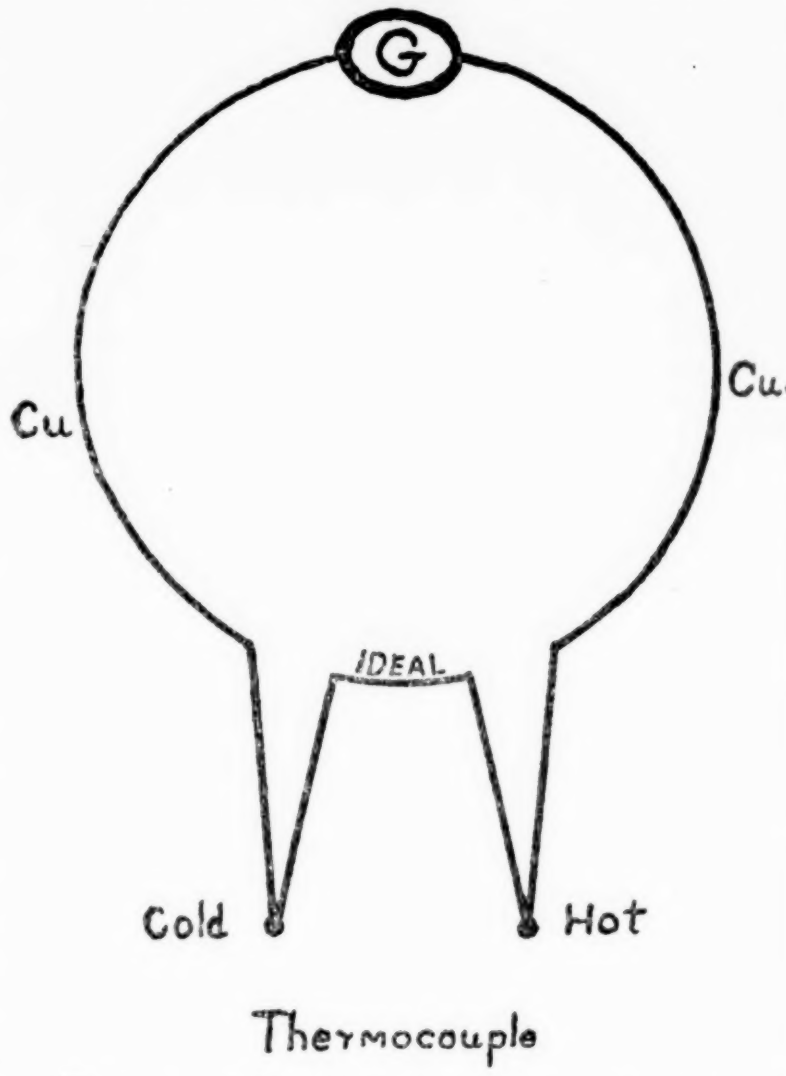

Fig. 1.—Diagram of simple thermocouple circuit with galvanometer.

For the measurement of temperature changes the ordinary laboratory precision thermometer was used in some of the experiments, but in the greater number, the temperature in the different portions of the subject was measured by electrical thermal junction thermometers, or thermocouples, by the galvanometer deflection method (7) (8) (see Fig. 1). The diagram of the apparatus used for these experiments is shown in Figure 2.

A vertical beam of light from an electric lamp was deflected by means of a right-angled prism upon the mirror of the galvanometer coil in the wall. The beam was reflected

[1] A grateful acknowledgment is extended to C. P. Yaglou of the faculty of the Harvard School of Public Health for his assistance in the assembling and use of the apparatus. The diathermy machine used in these experiments was provided through the courtesy of the McIntosh Electrical Corporation.

back through the prism and thence fell vertically upon a scale marked in centimeters. By placing a resistance in series, the galvanometer deflection could be checked within the scale limits, and a resistance in shunt dampened the oscillation of the galvanometer coil. In order to eliminate the effect of any tension or stress in the coil, a reversing switch was placed in the circuit, by means of which the direction of the induced current could be reversed in order to obtain the average deflection in both directions.

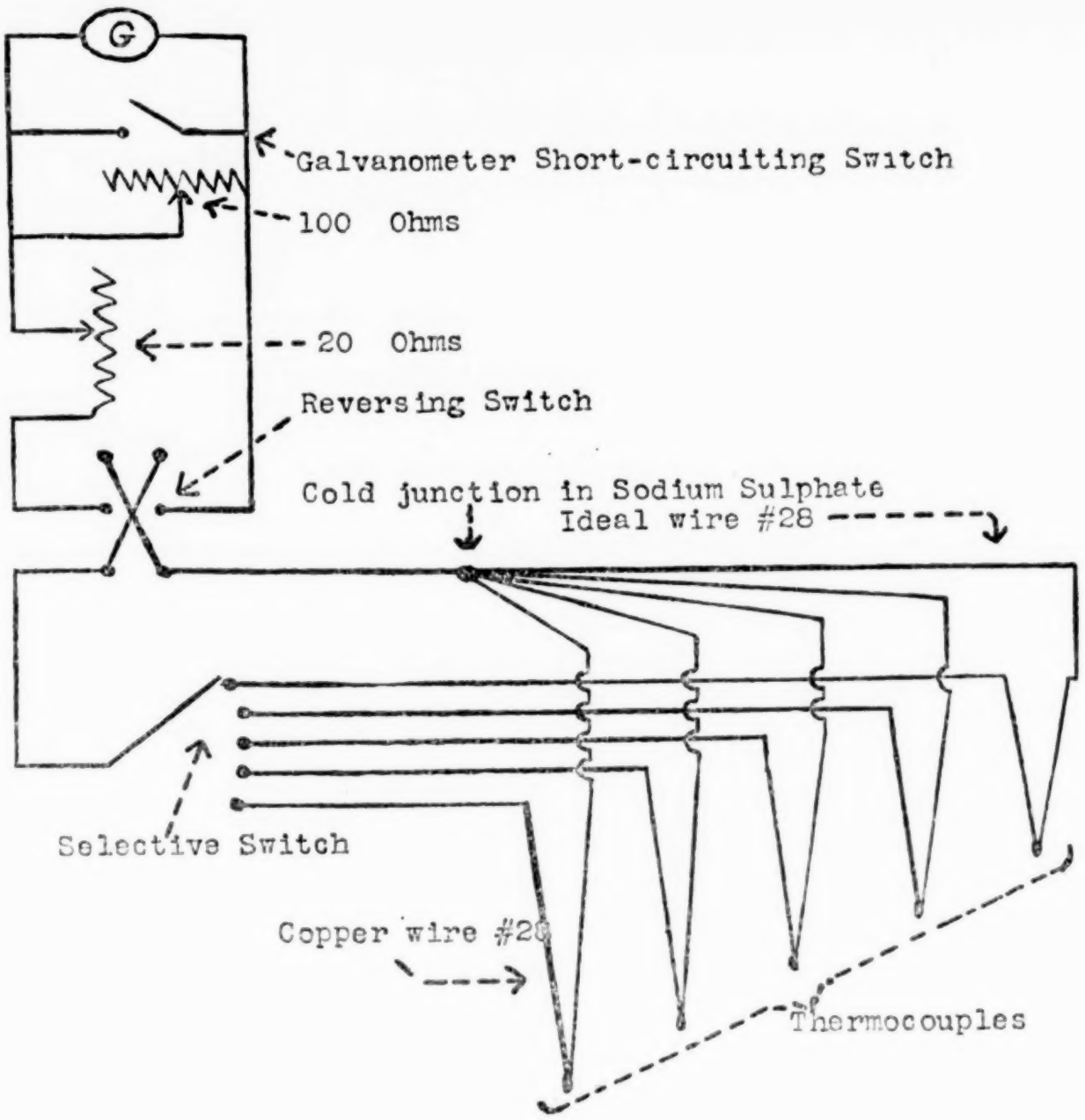

FIG. 2.—Diagram of apparatus used in experiments.

The thermal junction thermometers, or thermocouples, were made by fusing the ends of No. 28 copper and Ideal[2] wires and housing the couple in a 1-inch section of thin glass tubing. One open end of the glass tubing was sealed in the flame and the fused portion filed until the partition between the lumen and the exterior was quite thin. The thermal junction was inserted through the open end until it approximated the closed end of the tube, and then the outcoming insulated wires were held in place with sealing wax. The wires from the thermocouples to the selective switch were housed in rubber tubing for

[2] "Ideal" is the trade name of the nickel alloy wire used in the thermocouples.

protection and in order to facilitate handling. Four such thermocouples were made and in the fifth, which was to be used for recording joint temperatures, the thermal junction was not protected by glass tubing but was coated with shellac.

All five thermocouples had a common cold junction immersed in a Dewar flask containing molten sodium sulphate. The latter has a melting point of 90.3°F. which can be maintained in a thermos bottle for several hours. The cold junction was thus kept at a fairly constant known temperature somewhat below the temperature to be measured. The system was calibrated with the hot junctions in water of known temperatures, so that for every deflection the temperature of the hot junction could be determined from a curve. While this method is simple and convenient, it introduces a slight error in case the circuit resistance changes. In these experiments, however, the resistance of the circuit was always the same because the room temperature was practically the same.

The potentiometer method for recording temperatures, as described by Benedict and Slack (9), and others, is perhaps in more common usage for recording body temperature; yet for this purpose the apparatus just described seemed to be sufficiently accurate and adaptable.

Observations

On Nonliving Tissue

In the experiments carried out on nonliving tissue, potatoes, fleshy meat, and lamb joints were used; several interesting points developed. Nonliving tissue may be coagulated with diathermy, with temperature elevation depending on the variations in size, milliamperage, length of application, and mode of application. Coagulation of the tissue is not always perfectly uniform, though the uniformity increases as the time is extended, other factors being equal. Curves from the experimental data, as in Figure 3, show a marked rise in the temperature, which gradually reaches a constant level when the heat losses by radiation, convection, and evaporation balance the heat input in the form of electrical energy, the milliamperage and other factors being unchanged. It was observed that the presence of tissue juices in the fleshy meat exerted a dampening effect on the coagulation, for the lowest portion, to which the juices gravitated during the application of heat, was less well coagulated than the portion immediately above.

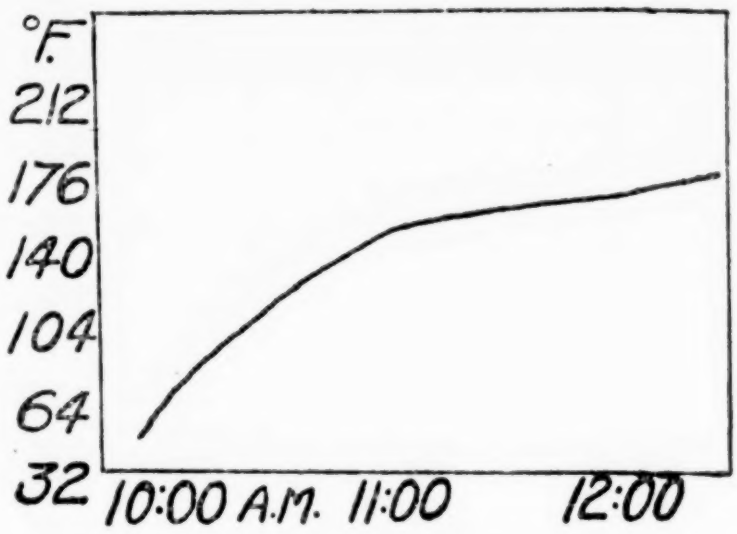

Fig. 3.—Showing temperature curve of potato after diathermy application of 1,000 milliamperes.

On Living Tissue

Experimental work on living tissue involved several different objectives, one of which was the effect of

TABLE 1.—TEMPERATURE CHANGES IN A DOG AFTER DIATHERMY APPLICATION TO (1) HIP JOINT AND (2) ELBOW JOINT

TEMPERATURE		HIP JOINT	VAGINA	RIGHT ELBOW
Hip Joint (*500 milliamperes applied for 1 hour and 15 minutes*)		°F.	°F.	°F.
Average	Initial	99.46	99.32	.....
	Maximum	100.41	.....	.....
	Final	100.31	98.69	.....
Variation		+0.85	−0.63	.....
Elbow Joint (*600 milliamperes applied for 20 minutes*)		°F.	°F.	°F.
Average	Initial	99.73	98.69	98.01
	Maximum	.....	.....	100.09
	Final	98.74	98.33	100.05
Variation		−0.99	−0.36	+2.04

TABLE 2.—TEMPERATURE CHANGES IN A DOG AFTER DIATHERMY APPLICATION TO (1) ELBOW JOINT AND (2) HIP JOINT

TEMPERATURE		RECTUM	ELBOW	
			Subcutaneous	In Capsule
Elbow Joint (*500 milliamperes applied for 1 hour and 5 minutes*)		°F.	°F.	°F.
Average	Initial	100.67	99.45	99.78
	Maximum	.....	101.91	102.20
	Final	100.08	101.78	101.93
Variation		−0.59	+2.33	+2.15
Hip Joint (*600 milliamperes applied for 30 minutes*)		°F.	°F.	°F.
Average	Initial	99.86	99.41	99.77
	Maximum	.....	100.85	101.03
	Final	100.13	101.03	101.21
Variation		+0.27	+1.62	+1.44

diathermy on the joint. In these experiments dogs were used. The animals were anesthetized by an injection of 5 per cent. sodium barbital in the femoral vein. The anesthetization was maintained evenly for several hours and was found to be a suitable method throughout the investigation. When anesthesia had been established, the joints were exposed by sharp dissection, and thermocouples were inserted within the capsule, in the case of the glass covered junction, or between the articulating surfaces if the shellacked fine-wire junction was used. In some cases an additional junction was placed subcutaneously, and in all animals either a rectal or a vaginal couple was inserted to record the body temperature. The tissues were then approximated with sutures and each lead was carried through a skin incision at some distance from the joint location and buried subcutaneously, in order to facilitate the close approximation of the lead-tin electrode plates directly over the joint.

In Table 1 the temperature variations in the hip joint of the dog are shown after an application of diathermy for one hour and fifteen minutes with a milliamperage of 500. The thermocouple was located within the capsule of the joint. Following this experiment a second attempt was made with the same animal, applying the electrodes to the elbow joint for a period of twenty minutes with a milliamperage of 600.

A similar experiment is recorded in Table 2, where, first, diathermy at 500 milliamperes was applied to the elbow joint of the dog for one hour and five minutes, using a fine-wire junction for recording the temperature, and secondly the hip joint temperature was measured for a period of thirty minutes, at 600 milliamperes. In both tables the second experiment followed within a few minutes the conclusion of the first. Lead-tin electrode plates, each measuring about 2 square inches, were secured by rubber bands to the internal and external lateral surfaces of the elbow joint, though it was found difficult to secure accurate approximation. In applying diathermy to the hip joint, each electrode measured 6 square inches; one was placed laterally and dorsally over the region of the great trochanter, while the second was fastened on the medial surface of the thigh as high as the perineum would permit. In all cases the electrodes were applied to the shaved surface of the skin.

In general, the body temperature underwent a gradual fall during the course of the experiment, although it may be seen that in Table 2 a slight rise in the rectal temperature followed the application of diathermy to the hip joint—an effect which was probably due to the proximity of the source of heat to the rectum. The temperature was increased in both joints and to a greater extent in the elbow, the more superficial of the two. Subcutaneous thermocouples gave temperatures paralleling those recorded in the joints, though the total rise was somewhat greater, owing largely to the fact that the initial subcutaneous temperature was lower (as shown by Macleod and Taylor (5)) than the deeper joint temperature.

In the next experiment a large dog weighing about 32 kilos was used,

and four thermocouples were located as follows: one in either side of the retroperitoneal fat, posterior to the kidney, and one in either hip joint, after space had been made by resecting a small portion of the head. The operations were rather extensive and it seemed that the animal suffered a moderate degree of shock. Diathermy was applied through two electrodes, each measuring 18 square inches, and these were secured laterally and medially about the region of the left hip joint. Body temperature was estimated by an ordinary laboratory thermometer inserted in the rectum. Diathermy was applied continuously for one hour and eighteen minutes at a milliamperage varying from 1,000 to 1,175. It was noticed that the animal's general condition gradually grew worse, and respirations ceased after forty minutes. The experiment was continued, however, for thirty-eight minutes longer. It was observed that the local temperature in the left hip showed a fairly constant rise approaching an equilibrium temperature, while perhaps more striking was the sharp rise in temperature which occurred after death had taken place. The temperatures in the left kidney region and in the rectum exhibited a slight rise, which became more abrupt after death. On the right side the tempera-

TABLE 3.—TEMPERATURE CHANGES IN A DOG UNDER DIATHERMY BEFORE AND AFTER DEATH

TIME	MILLIAMPERAGE	TEMPERATURES				
		Left Kidney Region	Left Hip	Right Kidney Region	Right Hip	Rectum
p.m.		°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
12:28	0	101.28	100.76	101.57	101.35	101.30
12:35	1,000	101.19	102.97	101.35	101.35	101.48
12:40	1,075	101.24	104.32	101.50	101.48	101.48
12:47	1,075	101.26	105.53	101.46	101.52	101.84
12:54	1,175	101.48	106.48	101.60	101.68	102.02
1:08	1,175	101.88	107.15	101.90	102.00	102.56
1:09	1,175	Respirations ceased.				
1:14	1,175	102.00	108.32	101.93	102.20	102.74
1:27	1,175	102.91	111.73	101.93	102.47	103.64
1:33	1,175	102.95	114.08	101.80	102.68	104.36
1:46	1,175	103 14	117.19	101.66	102.83	104.72

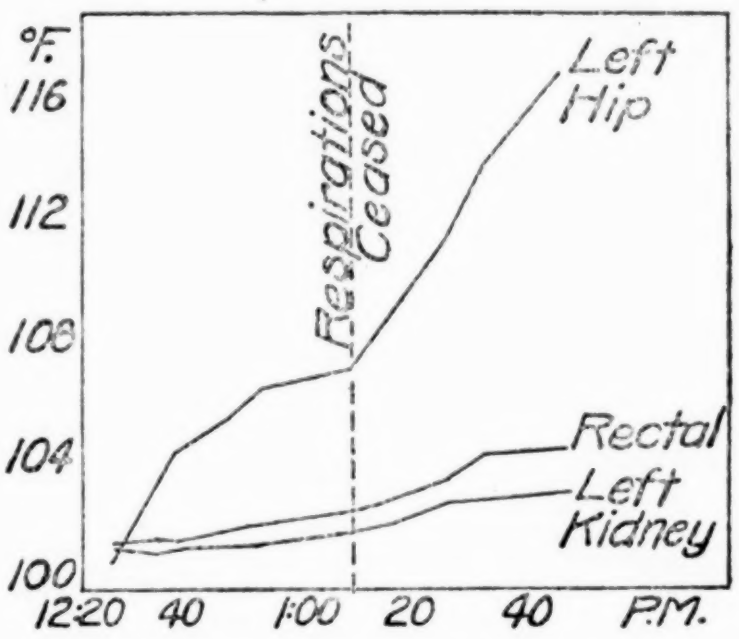

FIG. 4.—Temperature changes in a dog under continuous diathermy before and after death.

tures paralleled those found in the left kidney region until death, and then continued to rise but to a much less extent, the final temperature in the right kidney region—the farthest removed from the source of heat—being the lowest. A more graphic conception of the events may be obtained by referring to Table 3 and to the accompanying chart (Fig. 4). The most interesting feature of the experiment was the remarkable change in the temperature measurements which occurred after death. Death may have been due to an overdosage of anesthetic or to the surgical shock attendant on the operative procedures, which were extensive and long continued, though possibly both factors played a part.

An effort was made to secure the temperature measurement of the knee joint in the human subject. Two electrode plates, each measuring 133 square inches, were placed as indicated in Figure 5. Several applications were necessary before a comfortable treatment could be given, diathermy in the meantime being interrupted. The thermocouple was placed in the popliteal space, an artificial cavity being formed with the knee sharply flexed. The treatment consumed one hour and ten minutes, at a milliamperage varying from 500 to 900; the initial temperature of 98.33°F. rose to 103.28°F.—a difference of nearly 5°.

The experiment emphasizes several points, such as the individual reaction to the application of diathermy; the importance of careful, even approximation of the plates to the skin, either with the protection of bony prominences or their avoidance; and suggests that the response on the part of the patient should afford a reliable index as to the increase or decrease in the strength of the current. An increase in the strength of current despite the patient's discomfort would no doubt result in tissue damage. In one of the first experiments diathermy was applied to an anesthetized cat weighing 4 kilos, at a milliamperage averaging 1,750. Plates were secured to the lateral abdominal wall, one on either side, each measuring 21 square inches. The experiment covered one hour's time and the animal showed signs of tissue damage, almost from the beginning, and was dead at the conclusion. Thermocouples had been inserted in the rectum and in the peritoneal cavity, registering an average initial temperature of 98.24°F. and at death a temperature of 119.2°F. Necropsy findings disclosed hard, raised welts in the skin immediately beneath the plates, the intestines were hard and nonflexible, the blood vessels of the omentum were deeply injected, and minute hemorrhages covered the surfaces of the viscera, while the lungs likewise showed evidence of diffuse hemorrhages. The experiment provided an index for the strength of current used in later work.

The difficulties of obtaining an accurate determination of the temperature of the lungs were apparent, yet it was thought that an approximate estimation of the thoracic temperature might be obtained by thermocouples placed deep in the esophagus. A dog weighing 4 kilos was used. A diagrammatic cross section of the thorax is shown in Figure 6, with the location of the plates, each

measuring 14 square inches. The thermocouple was inserted in the esophagus for a distance of 14 inches, measured from the front teeth. An average strength of 700 milliamperes was applied to these electrodes for one hour, and the thermocouple registered a slow, steady rise from 100.67°F. to 102.74°F., a difference of 2.07°. A second experiment performed under similar conditions, but with a milliamperage of 400 and applied for three-quarters of an hour, recorded a rise of 0.73°F. in the esophageal thermocouple. Under theoretically similar conditions, and with allowance made for error, these two figures are comparable.

The importance of determining the degree of temperature change in the thoracic cavity when a form of heat is applied becomes apparent when both medical profession and laity frequently assert the value of diathermy in the solidified lung of pneumonia. It is generally believed that the circulation is active in foci of pneumonic solidification. Our experiments failed to show a notable rise in the deep temperature of the thoracic cavity in the presence of a normal circulation, and it would seem that the circulation in a pneumonic lung would be equally effective in distributing locally directed heat. The extent of heat penetration is probably limited, and the heating of the parietal pleura will perhaps account for the relief of symptoms noted in pneumonic patients treated with diathermy.

In other experiments made for the purpose of determining deep body temperature, thermocouples were inserted in the rectum of the human subject, and diathermy was applied to plates over the abdomen and low

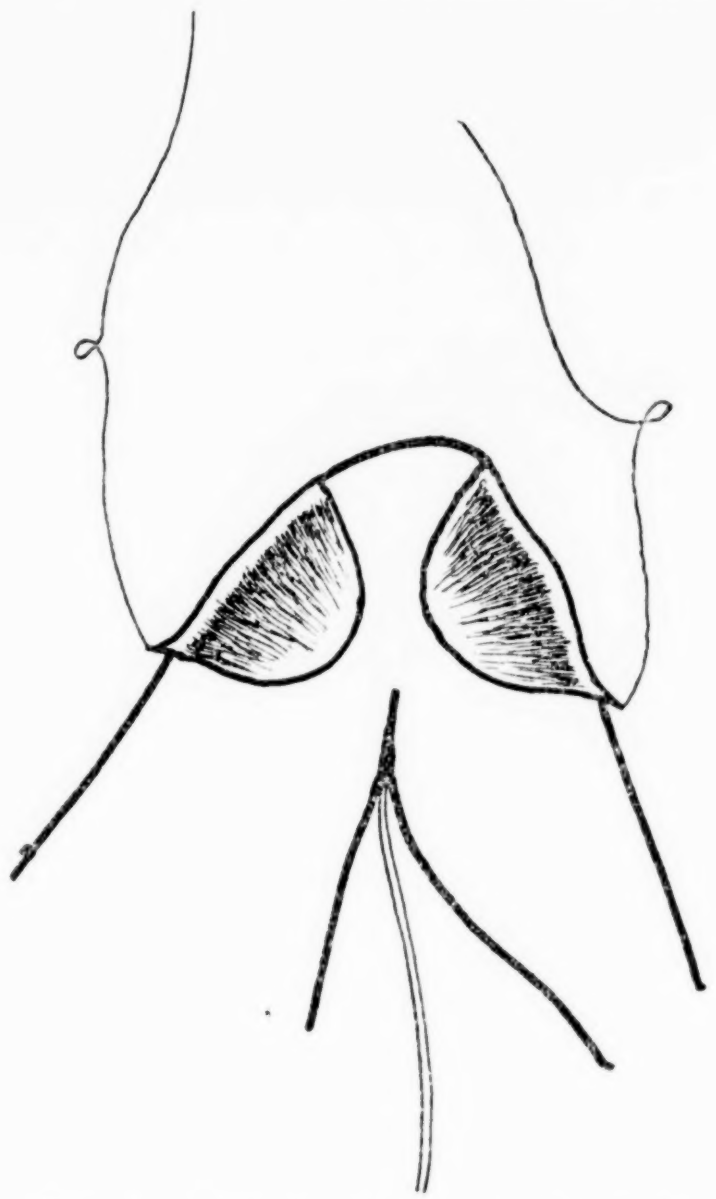

FIG. 5.—Diagram showing mode of electrode application on the right knee, the thermocouple being placed in the popliteal space.

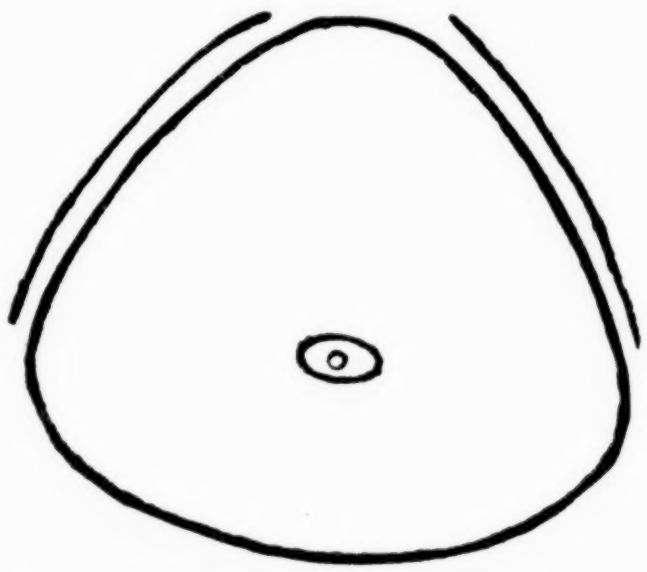

FIG. 6.—Diagrammatic cross section showing electrodes applied to the thorax of a dog with thermocouple inserted in the esophagus.

back. In one subject a thermocouple was inserted 14 inches in the rectum and electrodes measuring 105 square inches each were fastened, one over the lower abdomen, the other over the lumbosacral region. The current, averaging 3,300 milliamperes, was delivered for a period of twenty-five minutes. The patient experienced a local sense of warmth at first, which gradually increased until there was a sense of warmth throughout and the body was covered with perspiration. The temperature rose from 98.67°F. to 102.38°F.—a difference of 3.71°. In a succeeding experiment the thermocouple was inserted 2 inches in the rectum and one large plate of 64 square inches was placed over the lower abdomen, while a bipolar attachment, of two plates measuring 32 square inches apiece, was secured laterally over each buttock. Diathermy was applied at an average of 3,200 milliamperes for thirty minutes, and the total rise in temperature was 2.43°F. The sensation was similar to that in the foregoing experiment. In each case a mild diffuse hyperemia appeared in the skin directly beneath the electrodes.

Comments

At the conclusion of these several experiments certain observations obtained. The moderating effect which the normal circulation of the blood must exercise in preventing the local accumulation of heat must always be prominent. One may assume that any process which interferes with this normal state could account for a temperature elevation beyond the usual limits. In the case of the pneumonic lung, the respiratory function of the tissue in the diseased area is suspended, yet experimental data show that the focus is well circulated. Our records failed to disclose a notable elevation of the deep temperature in the thoracic cavity of the normal animal, and it appears doubtful that a marked elevation could be obtained in the well-circulated pneumonic lung.

Joints should prove better regions for the accumulation of heat, because they do not receive so active a circulation as that found in other organs. After diathermy, however, the elevation of the local temperature in joints was not noteworthy. It was observed that a difference in temperature of nearly 5°F. was attained after a diathermy treatment of the knee joint. Further, it is known that hydrotherapy, massage, electric pads, and other sources of external heat will elevate the superficial temperature as much as 5°F., while Macleod and Taylor (5) have shown that the heat from an electric pad may penetrate to a distance of 3 inches. The location of the joint, its surface anatomy, and the mode of application of the heat are all factors which greatly modify a local increase in temperature, and in these experiments the additional factor of an operation on the joint must be considered. We were unable, however, to detect a temperature increase after diathermy above that which could be obtained from other sources of external heat. Therefore, while an increase in joint temperature after an external heat application is more probable than the production of a similar change in other organs, the matter of circula-

tion must still play the important rôle in control and distribution.

One does not doubt the power of diathermy to cause an elevation of temperature in uncirculated tissue. This is a fact easily demonstrated, and it was interesting to note the abrupt change which occurred in the temperature following death (see Fig. 4).

The question of possible injury to tissues in the treatment of patients by diathermy is one to be carefully considered and dealt with. One has in diathermy a form of electrical energy which is not well understood. It is a powerful agent, apparently capable of causing gross injury, and by virtue of this fact must be used with caution. The control which is offered in the patient's subjective response represents a safety barrier and one which should not be forgotten. Tissue damage must result from the application of any form of heat beyond the endurance of that tissue. One may assume that with diathermy the heat is subject to a more accurate control and it is more evenly and uniformly distributed than in the application with hydrotherapy, massage, and electrical baking devices. It may, therefore, secure a greater penetration, yet the factors which govern and control its distribution must obtain here as in other methods of heat application.

That diathermy adds another valuable tool to our armamentarium is undoubted, yet indiscriminate use is to be discouraged and, as medical experience so often demonstrates, its practice must be *cum grano salis*.

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PREVENTIVE MEDICINE IN INDUSTRY

EXPERIENCE OF A WESTERN MAIL ORDER HOUSE*

C. O. Sappington, M.D., Dr.P.H.

Medical Director, Montgomery Ward and Company, Oakland, Calif.

IN THE December, 1925, number of the *American Journal of Public Health*, Dr. D. C. Parmenter (1) called attention to the great opportunity afforded the industrial hygienist for the practice of preventive medicine. He further commented upon the chance which each physician has, in his personal contact with employees during the physical examination, for the investigation of disturbances of function and minor disorders, which are often more important than actual organic disease.

Perhaps another important point may be added to these noteworthy observations: It seems rational to assume that a necessary step in the program of preventive medicine in industry would be the careful collection of data bearing on defects found in physical examinations and the character of the dispensary experience, with an analysis of this material and a constructive program adaptable to the correction of the defects observed and the institution of measures calculated to reduce the incidence of the chief types of functional disturbances.

With these ideas in mind, the experience of the Oakland, Calif., plant of Montgomery Ward and Company for the year 1925 is herewith presented. The Company conducts a general mail order business which presents mainly only those health hazards usually found where light manual labor and clerical work are done. The population varied between 703 and 1,170 during the course of the year.

Standards of Examination

The Company has provided that any employee who has been in service for a period of one year or more is entitled to any medical or surgical attention which is deemed expedient by the medical director, this work to be done at the Company's expense. With such a regulation in force, it became necessary to adopt high standards of acceptance in order that the expenses of the medical department would not be unduly increased in coming years.

Five classifications of examined applicants have been used:

1. Those unconditionally accepted.
2. Those accepted but needing special placement.
3. Those accepted, not needing special placement but needing follow-up work.
4. Those accepted provisionally (other than classes 2 and 3).
5. Those rejected.

* Received for publication Aug. 18, 1926.

The examination procedure followed closely that used in the larger industries at the present time and need not be given in detail. In applicants aged 40 or over, blood pressure readings and urinalyses have been done; attention has also been paid to weight and to chest and abdominal measurements. Considerable care has been exercised in searching for focal infection, principally with regard to tonsils and teeth, inasmuch as it has been shown that focal infection has been one of the chief causes for retirement on pension in the experience of some of the larger eastern industries.

Results of Examination

The results of the examinations of 1,350 applicants are shown in Table 1, tabulated according to examination classification, age group, and sex. Of the entire group, 64.3 per cent. were under the age of 20 years and 92.2 per cent. were under 30. Approximately the same percentage, 17.2 and 17.3, was provisionally accepted in both sexes. More than double the percentage of males as compared with females was rejected.

An important consideration in a preventive program in industry is a discovery of the defects possessed by the candidates presenting themselves for examination. The results for the present group are shown in Table 2. From the standpoint of percentage occurrence, the following defects appear to be worthy of mention: acne, underweight, history of dysmenorrhea, carious teeth, defective vision, enlarged and infected tonsils, various foot troubles, poor posture, simple thyroid enlargement, and transitory nervousness manifested by rapid pulse.

It was found necessary in the examination of applicants in this series to accept some provisionally with the idea that a subsequent examination would show a change or

TABLE 1.—EXAMINATION CLASSIFICATION WITH REGARD TO AGE AND SEX OF 1,350 APPLICANTS EXAMINED

CLASSIFICATION	AGE PERIOD					TOTAL	
	15–19	20–29	30–39	40–49	50–59	Number	Percentage
Males							
Accepted	384	162	30	9	4	589	77.5
Provisional	82	36	5	3	5	131	17.2
Rejected	24	9	2	3	2	40	5.3
Totals	490	207	37	15	11	760	56.3
Females							
Accepted	304	134	27	6	5	476	80.7
Provisional	67	32	2	1	0	102	17.3
Rejected	7	4	1	0	0	12	2.0
Totals	378	170	30	7	5	590	43.7

improvement in the condition. Two hundred and thirty-three were thus accepted, 131 males and 102 females. Table 3 sets forth the reasons for this provisional acceptance, the most important of which were: râles at one or both apices, rapid pulse, thyroid enlargement, and increased temperature. These occurred singly some-

TABLE 2.—PHYSICAL DEFECTS IN ORDER OF PERCENTAGE OCCURRENCE AMONG 1,350 APPLICANTS EXAMINED

DEFECT	NUMBER OF CASES	PERCENTAGE
Males (760):		
1. Acne	344	45.3
2. Underweight	342	45.0
3. History of serious illness	264	34.7
4. Carious teeth	186	24.4
5. Relaxed inguinal rings	160	21.0
6. Lung conditions	127	16.7
7. Defective vision	95	12.5
8. Relaxed transverse arches	83	10.9
9. Enlarged and infected tonsils	80	10.5
10. Varicocele	76	10.0
11. Flat feet	73	9.6
12. Poor posture	61	8.0
13. Rapid pulse	59	7.8
14. Loss of over 1 week in past year	54	7.1
15. History of major operation	53	7.0
Females (590):		
1. History of serious illness	195	33.0
2. History of dysmenorrhea	171	29.0
3. Underweight	168	28.5
4. Carious teeth	90	15.2
5. Rapid pulse	81	13.7
6. Acne	73	12.4
7. Defective vision	65	11.0
8. History of major operation	64	10.8
9. Enlarged and infected tonsils	55	9.3
10. Loss of over 1 week in past year	51	8.6
11. Poor posture	48	8.1
12. Rise in temperature	42	7.1
13. Thyroid enlargement	41	6.9
14. Lung conditions	36	6.1
15. Overweight	24	4.0

TABLE 3.—DEFECTS OCCASIONING PROVISIONAL ACCEPTANCE OF 233 APPLICANTS (17.2 PER CENT.) AMONG 1,350 EXAMINED

DEFECT	NUMBER OF CASES	PERCENTAGE
Males (131):		
1. Râles in one or both lungs	78	59.5
2. Rapid pulse	23	17.6
3. Increased temperature	5	3.8
4. Badly infected tonsils	4	3.1
5. Irregular heart	4	3.1
6. Defective teeth	3	2.3
7. Thyroid enlargement	3	2.3
8. Defective vision	2	1.5
9. Unguinal hernia	2	1.5
10. History of bronchial fistula	1	0.8
11. History of otitis media	1	0.8
12. Infected teeth and tonsils	1	0.8
13. Dental abscess	1	0.8
14. Head injury	1	0.8
15. Urinalysis	1	0.8
16. Testicular tumor	1	0.8
Females (102):		
1. Thyroid enlargement	33	32.4
2. Rapid pulse	16	15.7
3. Râles in one or both lungs	23	22.6
4. Increased temperature	20	19.9
5. Badly infected tonsils	2	1.
6. Otitis media	2	1.9
7. Irregular heart	2	1.9
8. Badly infected teeth	1	0.9
9. Defective vision	1	0.9
10. Unstable nervous system	1	0.9
11. Urinalysis	1	0.9

times and at other times in various combinations.

Less frequently it was found necessary to reject applicants. The causes for rejection are exhibited in Table 4. While the numbers are too few to permit deductions, valvular heart disease, recent otitis media, high blood pressure, and cystitis figure here.

TABLE 4.—CAUSES FOR REJECTION OF FIFTY-TWO APPLICANTS (3.9 PER CENT.) AMONG 1,350 EXAMINED

DEFECT	NUMBER OF CASES	PERCENTAGE
Males (40):		
1. Valvular heart disease	11	27.5
2. Recent otitis media	4	10.0
3. Probable tuberculosis	3	7.5
4. Inguinal hernia	3	7.5
5. Varicose veins	2	5.0
6. Defective vision and hearing	2	5.0
7. Spinal curvature	2	5.0
8. Varicocele	2	5.0
9. Head injury	2	5.0
10. Myocarditis	1	2.5
11. Glandular deficiency	1	2.5
12. Fractured skull	1	2.5
13. Venereal disease	1	2.5
14. Loss of one eye	1	2.5
15. Testicular tumor	1	2.5
16. High blood pressure	1	2.5
17. Low blood pressure	1	2.5
18. Encephalitis and sequelae	1	2.5
Females (12):		
1. Otitis media	2	16.7
2. Valvular heart disease	2	16.7
3. High blood pressure	2	16.7
4. Cystitis	2	16.7
5. Head injury	1	8.3
6. Encephalitis	1	8.3
7. Goiter	1	8.3
8. Defective vision—unstable nervous system	1	8.3

The experience with dispensary cases is interesting in that it followed fairly closely that of another industry (2) regardless of age grouping or type of work. Abnormal conditions occurred in the following order from the standpoint of greatest frequency: colds, headache, dysmenorrhea, lacerations of fingers and hands, gastrointestinal complaints, accidents other than those noted, skin lesions, pharyngitis and tonsillitis, eye and ear conditions, dental affections, and sprains and strains. The heaviest dispensary work was experienced in the months of February, March, July, October, November, and December, and was probably due to three factors: seasonal changes in the weather, increase in minor accidents (causing a larger number of successive treatments and redressings), which, in turn, was due largely to increased business (Table 5).

Preventive Program

Follow-Up Work.—It is recognized that there is little value in careful examinations unless follow-up and correction of defects found are actually done. After this year of experience, an extensive but simple follow-up scheme is about to be instituted.

Improvement of Working Conditions.—While the employees are now housed in a modern building and every effort is being made to make them comfortable and efficient, there will probably always be room for improvement. A consideration of the relation of the employee to his environment and of

TABLE 5.—DISPENSARY EXPERIENCE BY MONTHS: ACTUAL NUMBER OF CASES

Abnormal Conditions

MONTH	COLDS	HEADACHE	DYSMENORRHEA	GASTRO-INTESTINAL COMPLAINTS	SKIN LESIONS	PHARYNGITIS AND TONSILLITIS	EYE AND EAR	TEETH
Jan.	78	57	31	20	23	19	24	8
Feb.	44	53	26	22	18	15	13	9
March	50	29	24	10	13	26	16	10
April	60	25	33	25	17	19	18	3
May	29	25	25	17	17	10	12	6
June	31	26	23	46	24	16	14	9
July	15	33	28	26	23	20	12	9
Aug.	54	29	28	22	28	12	11	8
Sept.	32	27	26	22	16	8	10	9
Oct.	68	43	36	45	27	14	17	17
Nov.	90	25	30	21	18	13	20	6
Dec.	93	25	33	35	15	40	16	9
Totals	644	397	343	311	239	212	183	103
Av.	53.7	33.1	28.6	25.9	20.7	17.7	15.3	8.6

Accidents and Miscellaneous Items

MONTH	LACERATIONS OF HANDS AND FINGERS	STRAINS AND SPRAINS	ALL OTHER ACCIDENTS	PASSES HOME	MINOR OPERATIONS	SUCCESSIVE TREATMENTS	TOTAL CASES	EXAMINED FOR EMPLOYMENT
Jan.	42	9	28	37	2	203	501	129
Feb.	28	6	24	38	4	286	648	179
March	13	11	40	57	0	223	637	24
April	40	5	16	23	2	108	481	29
May	33	6	10	17	1	202	401	84
June	30	12	5	13	2	181	433	108
July	23	4	24	24	5	266	544	64
Aug.	28	8	18	23	4	192	496	150
Sept.	27	8	8	24	8	190	457	237
Oct.	21	14	14	22	4	308	750	195
Nov.	15	10	12	12	1	263	652	288
Dec.	31	8	52	33	3	277	771	138
Totals	331	101	251	323	36	2,699	6,771	1,625
Av.	27.6	8.4	20.9	26.9	3	224.9	564.3	135.4

his hygienic reaction to the work is now under advisement.

Health Education.—This is not the least important of the various phases of our constructive efforts. Its difficulty of accomplishment is, however, as great as its importance. Perhaps the best opportunity is presented at the time of examination or when the worker visits the dispensary for some indisposition. These occasions have been used to good advantage but must also be supplemented by other methods of instruction. A plan is now under consideration by which a discussion of the principal defects found at examination and the common functional and pathologic disturbances in our dispensary experience may reach every member of the organization by means of printed pamphlets. It is hoped that this may later be augmented by the use of lantern slides and motion pictures.

Discussion and Prospect

The examination and dispensary experience of a young group of industrial workers has been presented. It is probably typical of any similar age group in a like organization anywhere in the country.

In a recent investigation, the San Francisco Tuberculosis Association has discovered that approximately 90 per cent. of the pupils of the public schools in the region of San Francisco Bay leave the grade or high schools to enter industry direct. Because of this fact and also because the majority of the plant personnel are under the age of 20, two specific opportunities are presented: (*a*) possibility of checking up the efficiency of the school health program in districts from which employees are drawn (3); (*b*) the inculcation of proper health thoughts and habits during the period of intellectual malleability.

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MOISTURE AS AN ETIOLOGIC FACTOR IN INDUSTRIAL INFECTIONS*

C. W. Goff, M.D.

Cheney Brothers, South Manchester, Conn.

THIS report demonstrates the increased incidence of infections of the hands and forearms of a group of textile operatives with relation to the presence of moisture as an important etiologic factor.

In the mills from which this report is taken the raw silk is received in the form of split cocoons and frisons—that is, the waste silk from the winding processes which is in a more or less dirty condition. The bales are opened and their contents are dumped into a large vat where the silk material is boiled with soap and olive oil for a short time. This wet material is then dried in large steam ovens and turned over to the next group of operatives, who put it through a series of combings, during which it is sprayed and handled in a slightly dampened state. During the second and subsequent combings and cardings more moisture is necessary. The third group of operatives studied is taken from this process. Their hands are continually damp or actually wet, a condition which is necessary at this period in the preparation of silk. The second group of operatives studied was selected from those who handle the silk during the first combing process, when the silk material is just damp enough to be workable and not actually wet as in the subsequent process.

In the first group but two of the six operatives had suffered infections of the hands and forearms. These infections followed lacerations sustained during work, one progressing to a subacute tenosynovitis of the forearm and one developing an abscess of the forearm. Four of the six had not suffered an infection that could be demonstrated.

In the second group of forty-four operatives, there was a total of sixty injuries with thirty-one infections of the hands or forearms resulting. They were essentially the same in type as in the other groups. Twenty-five operatives in this group had not suffered any demonstrable infection of the hands or forearms.

In the third group of forty-one operatives there was a total of 151 injuries to the hands or forearms with 117 infections resulting, ranging in severity from simple infections of lacerations of the fingers to cellulitis of the hand, acute paronychia, and tenosynovitis of the forearm. Only five operatives had not sustained some form of infection.

It would seem from these observations that the incidence of infection of the hands and forearms is highest

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in the third group of operatives, who handle the silk material in the wettest condition and whose hands and forearms are subjected, therefore, to a continual softening with maceration. The first group of operatives, who handle the silk material directly from the bales and through the washing and drying processes, do not come in direct contact with the silk. They use applicators and gloves. Thus their hands and forearms are not in a wet condition. The second group of operatives are subjected to some moisture but to very much less than are the third group.

White (1) classifies all skin affections acquired in a trade as "trade dermatoses." He states that such affections exist in particular trades or occupations which produce a lowered resistance of the skin structures and a diminished reactive capacity, thus enabling some physical or chemical agent to cause an unfavorable reaction. Potton (2) has described a condition in the silk winders of France which he calls "silk winders' dermatosis," occurring on the hands and forearms of certain workers who wind the silk from the cocoon. He suggests that it might be due to the dead chrysalis with its decomposition products which irritate the hands of the workers and act together with the maceration processes of the water in which the cocoons are soaked. This condition is a moderately severe affection, sometimes resulting in a lymphangitis with constitutional symptoms. Vallin (3) believes this condition is due to the presence of an acarus, a parasite of the cocoon. Lehmann (4) has reported a skin affection in silk workers which results in pustules appearing on the arms and hands, and is called *mal des bassines*.

Much work has been done in the cutting trades in which saponaceous and oleaginous liquids are used. The workers suffer from a dermatosis of the hands and forearms with infections predominating. Hayhurst (5) reports exhaustive research along these lines. He calls attention to the reports of Purdon in Belfast in 1867, of Leloir in Belgium in 1889, and of Collis in Great Britain in 1910 in which infections of the hands and forearms of workers in the cutting trades appeared with great frequency. Dr. Collis believed that materials containing such substances as olive oil, light mineral oil, turpentine, olein emulsions, caustic alkalies, and phenol derivatives have one property in common—namely, that they dissolve or paralyze the secretion of the sebaceous glands, so leaving the cuticle open to infection. The infectious material may be in the form of solutions used in the trades or it may come from the frequent wiping of hands on the dirty clothing or waste used in some trades for cleaning the hands. Several investigators have found pyogenic organisms in the oils and compounds used as a lubricant in the cutting trades. These unfavorable conditions have been overcome by precautionary measures, as represented by the bulletin published by the National Safety Council on "The Prevention of Skin Troubles from Cutting Oils and Emulsions" (6).

In place of the oils and emulsions of the cutting trade, the silk operatives use tap water which frequent bacteriologic examinations show to be reasonably free from pyogenic organisms.

The silk workers, of course, wipe their wet hands on their overalls and on none too clean towels and rags. Thus one source of infectious material enters. Their personal hygiene out of the mills is above the average, yet may furnish some source of infection. The silk material has been boiled prior to handling by the second and third groups of workers and is practically sterile. Sticks, rollers, and machines which are used are not sterilized and may offer a constant source of infection though of a very low grade and apparently of little importance. The possibility, as suggested by Potton and Vallin, that the decomposition products of the chrysalis and its accompanying parasite may be an irritating agent to the hands and forearms with infection following as a secondary factor is quite probable. This may also be one very important element in the delay of healing of infections and of simple, noninfected injuries to the hands and forearms, which has frequently been observed by the author. Kershaw (7), of the National Safety Council, from his experience believes that skin infection in similar departmental processes in woolen mill workers "is due to a weakness on the part of the individual." He no doubt wishes to convey the thought that the "weakness" lies essentially in the skin exposed to the added moisture.

Discussion

After eliminating the individual job hazard, the figures for the three groups studied show that Group 3, with 78 per cent. of injuries infected, has by far the greatest proportion of infections of injuries to hands and forearms; Group 2 coming next, with 50 per cent. infected; and Group 1 last, with 33 per cent. infected.

The only variable factor of practical importance is the degree of moisture of the material and the hands of the workers. Welch (cited in (8)) calls attention to the now well-established fact that there is practically always present in the lowest layers of the skin the Pyococcus albus (Micrococcus epidermidis). Such being the case, when moisture is constantly present in amount sufficient to produce a more or less macerated condition of the hands and forearms, the native resistance to the organisms present is greatly diminished and they thrive with added vigor and develop all types of infectious manifestations.

Conclusion

This study indicates that moisture must play a greater part than is generally realized in the production of infections. Its significance can readily be drawn from the severity of the infections found in the groups of operatives studied.

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RESULTS OF REMOVAL OF DENTAL FOCAL INFECTIONS*

R. J. DeMotte, M.D., and Ernest Goldhorn, D.D.S.

Chicago, Ill.

THE causal relationship between chronic dental infections and certain symptoms and diseased conditions in other parts of the body has been firmly established by Billings, Rosenow, Price, and many others; yet the importance of dental infections in the production of chronic and acute systemic diseases and symptoms is underestimated by physicians and dentists in general. There is scarcely a tissue or part of the body which has not been found diseased or damaged through dental focal infections. These infections have been the cause of untold suffering and disability. In this connection, reports of the results of laboratory and clinical research work now being done by Dr. Price of Cleveland should be studied with great care.

The results of eradication of dental foci of infection reported in the paper here presented were obtained in an industrial dispensary clinic of a corporation having 6,000 to 8,000 employees. The patients were mostly men, workmen in the shops; all nationalities were represented. The dental clinic was established three years ago, largely because the majority of dentists and physicians in private practice failed to appreciate the relationship between dental infection and systemic symptoms and refused to co-operate by insistence on the removal of the focal infection. It is difficult to convince the average patient that removal of infected teeth which are giving no pain will stop the pains of neuritis or arthritis in remote parts of the body. It is hard to convince him that his heart trouble, headaches, or nervous trouble may be related to these painless, devitalized teeth. In spite of our efforts to convince them that infected teeth should be removed, the large majority of patients seen at our dispensary do not follow our advice in this matter. A considerable number, however, have now been treated and records of their complaints and condition have been made. Only a part of the patients return for subsequent observation; in order to secure information as to the results obtained, therefore, the following questionnaire was mailed to all who, in the past three years, had had infected teeth removed for systemic ailments.

Dear Sir:

In order that we may learn from our patients the results of the removal of infected teeth on chronic ill health, we are sending this letter to several hundred men and women who have had such work done at our dispensary. If you will kindly answer the following questions, you will aid us in formulating our future policy. This information will be kept in strict confidence. Please mail in the enclosed envelope.

On....., you had some infected teeth removed at the Company Dispensary with the hope of relieving symptoms of .....

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1. Were you cured, relieved or unrelieved?.....

2. If cured or relieved, how soon after removal of infected tooth or teeth? .....

.....

3. Have you had any recurrence of the same trouble since that time?.....

.....

4. Do you feel that your general health was improved by removal of teeth? .....

.....

REMARKS:.....

.....

Thanking you for this information, I remain

Very truly yours,

This letter was sent to 237 patients. Replies were received from 185, or 78.1 per cent. Table 1 is a summary of these replies. Briefly, of 185 patients seeking relief from various systemic ailments, 152, or 82.2 per cent., were cured or relieved by removal of dental infections. The general health was improved in 138, or 74.6 per cent.

TABLE 1.—GENERAL RESULTS OF QUESTIONNAIRE SENT TO 237 PATIENTS

RESULTS	NUMBER	PERCENTAGE
Replies	185	78.1
Cured	106	57.3
Relieved	46	24.9
Cured and relieved	152	82.2
Unrelieved	33	17.8
General health improved	138	74.6
General health unimproved	47	25.4

Among these 185 patients, there were 36 who were suffering from myositis, either chronic or acute; 50 who were suffering from chronic arthritis; 43, from neuritis; 19, from chronic stomach trouble; and 37, from various other chronic ailments for which no adequate cause other than infected teeth could be found on physical examination (see Table 2). The last group included cases of chronic nose and throat trouble, chronic heart and kidney disease, chronic bronchitis, nervous trouble, and headaches.

Referring to Table 1, it will be seen that there were 33 patients who were not relieved of their systemic troubles after removal of infected teeth. When we came to analyze these cases, we found the following:

	Number of Cases
One or two infected teeth removed, but infected teeth still in the mouth which the patients refused to have removed	13
One or more infected teeth removed, but no X-rays taken; in these cases, there *may be* infected teeth remaining in the mouth	7
Died later of cancer of the stomach which removal of teeth could not affect	2
Died later of pernicious anemia	1
Chronic infection of the nasal sinus	1
Chronic infection of the middle ear	1
Chronic stomach trouble; one was not relieved; one was cured, but had medical treatment and special diet, so it was impossible to give credit to removal of infected teeth	2
Old injury to the arm	1
Pain in the lower part of the back which started with a heavy lift	1
General nervous trouble of three years' standing	1
Sciatic rheumatism; teeth removed Dec. 5, 1925; returned to work Dec. 30, 1925	1
Neuritis of several weeks' standing; no infected teeth removed until about three months after first advised to do so; was relieved temporarily	1
Chronic bronchitis of several years' standing	1
	33

If we eliminate 23 of the foregoing cases in which favorable results could hardly be expected, the percentage either cured or relieved was 93.8.

TABLE 2.—RESULTS OF REMOVAL OF DENTAL FOCAL INFECTIONS ON CHRONIC SYSTEMIC AILMENTS AMONG 185 PATIENTS WHO ANSWERED QUESTIONNAIRE

RESULTS			AVERAGE TIME	RECURRENCES		GENERAL HEALTH IMPROVED	
	No.	*%*	*wks./das.*	*No.*	*%*	*No.*	*%*
Myositis (36):							
Cured	19	52.8	5/—	1	5.3	19	100.0
Relieved	7	19.4	—/11	5	71.4	6	85.7
Unrelieved	10	27.8	.....	..	....	0	0.0
Arthritis (50):							
Cured	28	56.0	2/—	0	....	24	85.7
Relieved	16	32.0	—/39	13	81.2	13	81.2
Unrelieved	6	12.0	.....	..	....	1	16.7
Neuritis (43):							
Cured	25	58.1	—/20	0	....	24	96.0
Relieved	12	27.9	7/—	11	91.7	10	83.3
Unrelieved	6	14.0	.....	..	....	1	16.7
Chronic Stomach Trouble (19):							
Cured	8	42.1	—/40	0	0.0	8	100.0
Relieved	5	26.3	—/40	4	80.0	4	80.0
Unrelieved	6	31.6	....	..	....	1	16.7
Other Chronic Diseases (37):							
Cured	25	67.6	—/25	..	....	24	96.0
Relieved	6	16.2	—/40	2	33.3	6	100.0
Unrelieved	6	16.2	.....	..	....	2	33.3

We realize that the number of cases covered by this report is small and that no general conclusions should be drawn from them. The symptoms which brought some of these patients to the doctor might have disappeared, at least temporarily, if the infected teeth had not been removed. The percentage of cases cured or relieved is so high, however, that we feel justified in presenting the report for what it is worth. Our results seem to emphasize the importance of dental infections as the cause of systemic troubles. In spite of the good showing of our results and of those of others, it is well to avoid becoming too radical on this subject. There are other focal infections besides those that occur in the teeth. Each patient presenting symptoms which may arise from infected teeth should be given a thorough examination so that all reasonable information may be at hand on which to base an opinion as to the cause of the trouble. But the teeth are known to be the most frequent offenders, and education among the professions and the laity is needed to eliminate as far as possible this very common source of always troublesome and sometimes grave systemic

disorders. In this connection, the prevention of dental caries and the conservation of the healthy dental pulp are the all-important objectives. The filling of devitalized teeth should be discouraged. Where it is deemed necessary to remove the dental pulp, the most careful aseptic technic should be used.

It should be remembered that the tooth with the large area of bone rarefaction about its root is not the most dangerous one from the standpoint of systemic trouble. Devitalized teeth with no bone absorption about their roots or with sclerosis of the bone are more likely to be the guilty ones. It has been proved that badly decayed teeth which are still vital may have infected pulps and act as foci of infection producing systemic trouble. Pyorrheal pockets are often responsible for similar systemic ailments.

MASKS AND RESPIRATORS FOR PROTECTION AGAINST DUSTS AND FUMES*

J. B. Barreto, Philip Drinker, Jane L. Finn, and R. M. Thomson

Department of Ventilation and Illumination,
Harvard School of Public Health, Boston, Mass.

Introduction

IN MANY industrial operations, the liberation into the air of harmful dusts and fumes cannot be avoided, although conditions can often be improved by general ventilation, by local exhaust ventilation, by turbulent air currents, or by the watering and spraying of dusty places (1). Even with these precautions, the concentration of the dust remaining in the air may still be dangerous.

In the case of toxic and irrespirable gases, where the systemic effects of inhalation are rapid, the need for protection is generally recognized, and suitable gas masks, oxygen breathing apparatus, or hose masks (2) are available. Where dusts and fumes are concerned, it is much more difficult to arouse interest in protective devices, since the deleterious effect of inhalation often becomes apparent only after repeated exposure—sometimes after a few weeks and sometimes after as many years.

This paper, therefore, will be concerned with masks and respirators designed for daily protection against the inhalation of dust and fume particles.

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Dusts, Fumes, and Smokes Defined

Any attempt to classify suspensions of particulate matter in air in terms of the size of the particles is necessarily arbitrary and the distinction between the various classes is never sharply drawn. For the sake of convenience, however, we shall use the following three broad classes, described in a previous paper (3):

Dusts.—By dusts, we mean finely divided solid particles ranging in size from less than 1 micron up to 150 microns, with the median size falling below 10 microns. In industry, dust clouds coming within this classification are formed by operations such as grinding, crushing, drilling, and blasting.

Fumes.—Fumes signify liquid or solid particles from about 0.2 to 1 micron in diameter formed by physicochemical reactions such as distillation, condensation, and combustion. Acid mists, ammonium chloride, lead, zinc oxide, and the like can be produced in the form of fumes.

Smokes.—To the colloid chemist (4), smokes mean "aerosols" consisting of particles of ultramicroscopic dimensions (0.001 to 0.1 micron). For our purposes, we shall take smokes to mean the liquid or solid particles

about 0.3 micron or less in diameter) which are the products of incomplete combustion of carbonaceous matter—as, for instance, gas, oil or lamp blacks; tobacco, wood, or coal smokes.

Principles of the Gas Mask and of the Mask for Dusts and Fumes

Gas masks are designed to absorb small amounts of toxic gases. The chemicals which accomplish this absorption are usually in the form of granules about 3 mm. in diameter, arranged in one or more layers a few centimeters deep. Owing to the mutual affinity of these granules and the gas molecules and to the incessant kinetic molecular motion of the latter, a high absorption efficiency is obtained with little increased resistance to breathing. Most gas masks are also provided with felted filters at the entrance to the canister or between the layers of chemicals within. These filters have a small cross-sectional area, usually about 65 sq. cm., and are held tightly in place, so that there is no appreciable leakage. Gas mask filters can be made very efficient as dust, fume, and smoke removers, but their area is insufficient for long-continued use, because resistance to breathing becomes too great. Moreover, the chemicals which are essential for gas removal add materially to the weight of the mask, increase its cost, and do little service against dusts and fumes.

A different method, then, must be used for catching particulate substances. Their only real analogy to gas molecules is their brownian movement, which is insignificant compared with the motion of gas molecules. Particles suspended in air can be caught either by filtration or by violent impingement against a suitable collecting plate, as in electric precipitation (5). Of the two, the filtration method is better adapted for use in masks.

The most practical and efficient filters for protection against war smokes and fumes are those made of fibrous materials like cotton, wool, or pulp. The fibers of such materials intermesh, giving felt-like substances through which the air passages are tortuous and small, although not so small that the resistance to breathing becomes prohibitive.

Various Masks Described

United States Army Mask, Model 1919

The canister of the model 1919 United States Army gas mask (6) contains a filter whose total area is about 460 sq. cm. This filter is very effective and will catch suspensions as fine as tobacco smoke, but it is not available for industrial use. For our purposes, it serves as a convenient standard for comparison with various industrial masks.

Pig Snout Respirators

In the commonest dust mask, the pig snout respirator (Fig. 1), circular pads of felted cotton, filter papers, or sponges are used as filters. The thickness of the pads and papers may be varied according to need. The papers are used dry, the sponges usually wet, and the pads either wet or dry. All three types of mask are cheap and the filters are easily

replaced. Since the felted cotton and paper filters are small in area, they become plugged with the filtered particles and must be frequently renewed.

FIG. 1.—Pig snout respirator with cotton pad filter and rubber flap expiration valve (Sadd type). The filter pads are reenforced with fine gauze on each side. Respirators with sponge and paper filter are constructed in practically the same way. The body of the respirator shown is made of stamped aluminium and is covered at the points of facial contact with an inflatable rubber cushion.

The pig snout respirator can be obtained with or without goggles attached. It is simple, inexpensive, and fairly comfortable.

Burrell Dust Mask

It was pointed out by Fieldner (7) that effective dust masks could be made of filters which were rather dense and large in surface area. The Burrell dust mask (Figs. 2 and 3) is a comparatively new industrial mask embodying this principle. The effective filtering area (Fig. 3) is about 840 sq. cm., both sides serving as filters. These filters are reenforced within by a thin sheet of corrugated wire netting, which prevents collapse on inhaling, and are covered

FIG. 2.—The Burrell dust mask with Kops headpiece and noncollapsible tubing.

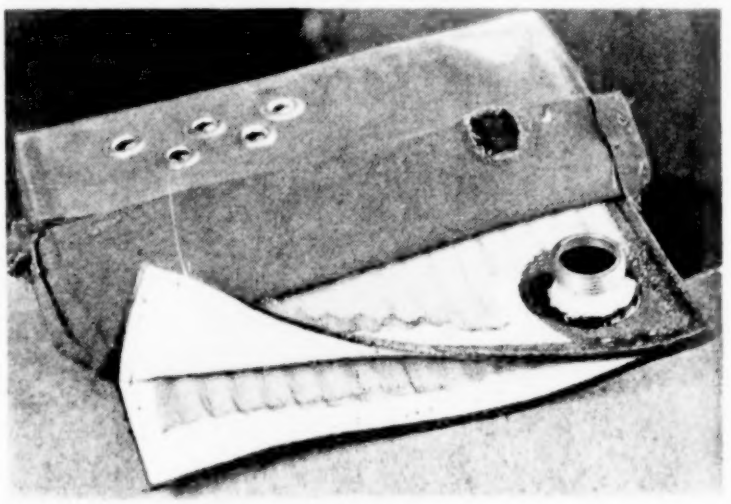

FIG. 3.—The Burrell dust mask showing construction with corrugated wire mesh to prevent collapse on inhaling.

with a coarse canvas bag perforated with several holes through which the air enters. Between the cover and the filters there are also sheets of corrugated wire netting. The filters are used with a gas mask facepiece (Kops type) and noncollapsible tubing containing a metal inlet valve (Tissot type) and having a rubber flap outlet valve (Sadd type) (Fig. 2). If the filters become plugged from use, they can be cleaned off by blowing compressed air into the threaded junction shown in Figure 3.

This mask affords excellent protection against dust and against a great many fumes; it removes a fine smoke such as tobacco at efficiencies of over 80 per cent.; and, because of its large area, it has a low resistance to breathing and very little tendency to plug on long usage. It is adapted to the severest sort of use—protection during sand blasting, for example—but it is more efficient than need be for many industrial dust hazards, and, like the gas mask, it is expensive.

Cotton Fabric Masks

In the industrial process of collecting zinc oxide fume, bag filters made of coarse and heavy cotton are sometimes used. Some fume passes through these bags at first, but after a few minutes the surface meshes of the fabric become plugged by the fume and the efficiency increases to practically 100 per cent. (8). From then on, the bags are effective and need no further attention until enough material has accumulated on the inner surface to make the resistance to air flow prohibitive. The fume is then shut off, the bags are shaken, the collected material removed, and the cycle of operations repeated.

Cheap and satisfactory dust and fume masks can be made by using this bag filter principle. Masks with a filtering area as great as 1,300 sq. cm. can be made of two layers of coarse muslin folded over a corrugated wire mesh and sewn tight at the seams. A breathing tube is inserted into the muslin and the addition of a suitable headpiece, tubing, and escape valve completes the equipment. As in the Burrell dust mask (Fig. 2), it is best to use a cover to keep the fabric from being torn and the accumulated dust from being brushed off. Masks of this particular type have not, as yet, been used in industry. Until they have been tried under actual industrial conditions, they should be considered as merely experimental and, with that limitation in mind, we shall refer to them frequently in this paper.

Headpieces and Accessories

It requires a very dangerous hazard to convince one that the complete gas mask headpiece (Fig. 2) and accessories are necessary for protection against the common industrial dusts and fumes. This equipment is hot and uncomfortable, particularly if the wearer is exercising vigorously. Furthermore, it impairs vision, and, for that reason alone, its application is limited to extreme conditions and to use by trained and intelligent wearers. Other forms of headpieces, to which canisters are screwed at a point just below the chin, are now available. There are also certain

other modifications made of molded rubber in one piece, but they, too, are uncomfortable. For dust masks, they offer simplification over the Kops headpiece, in that they omit the flexible tubing which connects the filters or canisters to the facepiece.

The facepiece of the better type of pig snout respirator is provided with replaceable, inflatable rubber linings, which are attached to a stamped metal (aluminium) frame made to fit the average face. In metabolism work and in resuscitation apparatus (oxygen-carbon dioxide process), molded facepieces of soft heavy flexible rubber are used.[1] Either this type or the inflatable rubber type will suffice for most industrial dusts or fumes. If protective goggles are necessary, they can be worn separately, or the facepiece may be obtained with goggles attached.

Expiration valves of the rubber flap (Sadd) or the disk (Tissot) type are provided with the pig snout facepieces. Inspiration valves and the flexible rubber tubing usually used in gas masks are omitted. These omissions simplify the equipment and make it much cheaper than that required for gas masks. On the other hand, the expiration valves of pig snout respirators are apt to leak badly.

Test Suspensions

Differences in Dispersion

Tobacco Smoke.—Tobacco smoke is a convenient suspension for testing masks and filters (10). It can be made very easily and it gives particles about 0.27 micron in diameter, with a variation of approximately 2 per cent. (11). Suspensions of tobacco smoke are harder to catch than those of the dusts or fumes commonly encountered in industry. A mask which catches tobacco smoke particles, then, can generally be relied upon to catch the coarser particles of dusts or fumes.

Dr. R. L. Sebastian[2] (12) has pointed out to us the following objections to the use of this suspension: "Tobacco smoke is a liquid smoke and affects the filter in an entirely different manner than solid smokes. While using solid smokes, the efficiency increases as the filter is used, with tobacco smoke the reverse is the case and the filter deteriorates with use. Thus prolonged exposure to tobacco smoke depending upon the texture of the filter and concentration of the smoke will give entirely different results than if the same filter is tested with a solid smoke of the same particle size and concentration."

We have encountered these same difficulties when using tobacco smoke for long tests; for very brief tests on industrial masks, however, we have found it satisfactory.

Fumes.—A fume which can be generated without difficulty in the laboratory is zinc oxide. It is produced by the ignition of about 1 part of potassium chlorate with 4 parts of zinc powder (commercial "blue powder"). Although the resulting sus-

[1] These were found satisfactory in the United States Navy Yard, Philadelphia, where a serious lead fume hazard occurred (9). The nature of this problem, however, made hose masks (2) more suitable than any gas or dust masks available.

[2] Chemical Warfare Service, Edgewood Arsenal, Md.

pension contains potassium chloride, potassium chlorate, and unburned zinc as well as zinc oxide, the system seems to possess the essential physical characteristics of pure, freshly burned zinc oxide fume. The particles are under 1 micron in size and are fairly uniform.

A finely divided magnesium oxide fume can also be made by burning magnesium ribbon. This fume possesses the great advantage of being easily determined chemically by titration with 0.1 N acids and alkalies.

Dusts.—Two different dusts were used in this investigation. The first, silica, is a finely ground product supplied by the Corning Glass Works. The particles range in size from about 0.5 micron to over 30 microns, with the median size falling between approximately 1 and 3 microns. The second dust, designated as "bag dust," is collected by bag filters in the metallurgic plant of the New Jersey Zinc Company at Franklin, N. J. This dust contains at least five minerals, it is reasonably constant in composition, and it gives smaller and more uniform particles than our silica. Of these two suspensions, the bag dust is the harder to catch both in dust masks and in respirators.

In a recent paper by Katz, Smith, and Meiter (13) on the efficiencies of respirators, a special type of silica known by the trade name of "silica smoke"[3] was used. Our examination of this material is in agreement with Katz' finding that the particles are about 1 micron in diameter—considerably less than the median size of our silica or bag dust particles. Consequently, the silica suspensions used by Katz are probably harder to catch than the dusts that we used. Our zinc oxides, on the other hand, are more finely divided than Katz' silica.[4]

Comparative Plugging Properties

In addition to differences in dispersion between these test suspensions, we must consider their respective tendencies to plug up the passages in the filters of the masks.

Tobacco Smoke.—As has already been pointed out, filters deteriorate from treatment with tobacco smoke, probably because of its oily nature, and consequently it cannot be used for plugging purposes.

Fumes.—Fumes like zinc oxide are quite dry and, if freshly formed, consist of particles with a strong tendency to aggregate and to increase somewhat in size. The extent to which aggregation occurs has been studied by Wells and Gerke (11); it is shown photographically by Whytlaw-Gray, Speakman, and Campbell (15); and it is discussed by Gibbs (4, p. 91). The practical significance of the aggregation of fume particles is that masks originally inefficient against tobacco smoke can be made efficient by drawing through them freshly formed fumes like zinc, magnesium, and aluminium oxides. After these fumes have remained in the air for a few hours, their ability to plug filters is greatly reduced. If the plugging process is to be used in order

[3] Made by the Eureka Flint and Spar Company, Trenton, N. J.

[4] We have given elsewhere (14) the comparative stability of the various test suspensions used.

to increase the efficiency of masks, therefore, it should be applied soon after the fume clouds have been formed, so that the particles will aggregate on the surface of the masks and not in the air before they reach the masks.

It should not be inferred that efficient plugging can be obtained with all types of fumes. When a fume shows little tendency to aggregate and its stability is not very much affected by turbulent air motion (1), its power to plug inefficient masks appears to be slight. Take, for example, lead bromide fume made by burning lead tetraethyl, ethyl bromide, and gasoline in a plumber's torch. Small amounts of this fume[5] at both high and low concentrations passed through all the masks that we have tested except the Army model 1919. We attempted to plug both the Burrell and our experimental cotton masks with this fume, but without success; yet both these masks could be made to catch lead fume, even in low concentrations, if they were first plugged with high concentrations of freshly formed zinc oxide fume.

Dusts.—Dusts made of ground particles like our silica will plug masks, but not by any means so effectively or so permanently as the much finer suspensions of fumes which have a tendency to aggregate. Filtering efficiencies of most industrial masks increase very rapidly, however, after a few minutes' treatment with a dust like silica. This effect is, of course, greater with high than with low dust concentrations.

[5] This contains some carbonaceous smoke in addition to the lead fume.

Determining Filtering Efficiencies of Dust and Fume Masks

Tyndallmeter Method

The filtering efficiency of masks is determined by measuring the concentration of suspensions entering (a) and leaving (b) the masks. In percentage, the filtering efficiency is then $(1 - b/a) \times 100$. The quantities a and b can be determined by measurements of concentrations—by electric precipitator, for instance, or by measuring the Tyndall effects in terms of arbitrary standards. Of the two, the former is the more sensitive, but the latter is much simpler, quicker, and more practical.

The United States Bureau of Mines compares the Tyndall effects (10) (16, p. 169) of the air entering and leaving the mask under examination. (The actual concentration need not be known.) In this method, 1,500 c.c. a minute of the suspension drawn through the mask passes through the Tyndall apparatus.

Instead of the Bureau of Mines Tyndall test, we prefer to use Tolman and Vliet's Tyndallmeter (14). With this apparatus, the concentration of the suspension entering or leaving the mask is measured photometrically in terms of the light reflected or scattered in the Tyndall beam—we do not match two Tyndall beams.

The two methods give about equally rapid results; the sensitivity of the Bureau's method is perhaps greater than ours with feeble Tyndall beams (efficient masks); whereas ours is probably more sensitive than theirs with strong beams (inefficient masks). We have the advantage of using the en-

tire amount of air flowing through the mask under examination and they use only a small fraction. On the other hand, our method requires that the initial concentration be known and theirs does not. Both methods require frequent cleaning of the chambers in which the Tyndall beams are viewed. Neither method gives reliable results if the masks are more than about 97 per cent. efficient, but that is accurate enough for our purposes. Where higher efficiencies are desired, the electric precipitator can be used.

Unless a test suspension is optically very dense, the relation between Tyndallmeter readings and concentration (in terms of numbers of particles or of weights of material per unit volume of air) is approximately linear. Under these conditions, it is within the limits of experimental error to assume that Tyndallmeter readings give a true index of concentration. It should, however, be remembered that the color of the particles, their size, and their dispersion all exert important and measurable effects on the strength of the Tyndall beam. Therefore, equal Tyndall readings on suspensions of different substances—or even of the same substance—do not necessarily signify equal concentrations.[6]

As the result of investigations for the origin of which the Bureau of Mines was largely responsible, 85 liters a minute was determined upon as a safe maximum test rate for gas masks (10).

A man of average size, seated and engaged in light exercise, breathes about 8 to 12 liters a minute; standing and exercising moderately, his minute-volume may increase to 15 to 20 liters; exercising vigorously, it may reach 30 to 40 liters. Whether or not he is exercising, out of each minute he spends something less than half in inspiring; the remainder is taken up with expiration and with a certain interval of rest between inspiration and expiration. In vigorous exercise, this interval practically disappears; but for men at rest or exercising moderately, it is usually appreciable.

The resistance to inspiration and the filtering efficiency must be estimated in terms of the inspiratory rate—something more than double the rate indicated by the minute-volume—not simply against the rate indicated by the minute-volume. We have tested filtering efficiencies and resistances, therefore, at 50 liters a minute (as the maximum inspiratory rate for moderate exercise) and at 85 liters (as the maximum for vigorous exercise).

Our procedure for testing the filtering efficiency of a mask by Tyndallmeter is as follows: The test suspension is set up in a 1,600 cubic foot gas tight cabinet (17), to an outlet of which the Tyndallmeter is attached. A vacuum pump within the cabinet, but controlled from without, draws the air from the cabinet through the Tyndallmeter and back again into the cabinet. A flowmeter is placed in the pipe line, so that the volume of air flowing through the Tyndallmeter can be read and controlled. One observer, wearing a mask, remains inside the cabinet and attaches masks to the entrance of

[6] The significance of these differences we have discussed elsewhere (14).

the Tyndallmeter as the observer outside the cabinet directs. Before tests of masks are started and at intervals

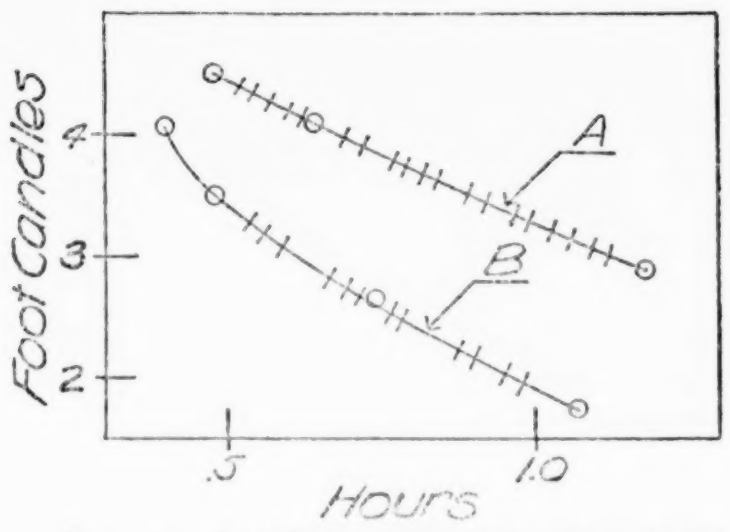

FIG. 4.—Settling curves of suspensions used in tests of respirators and masks. Curve A is tobacco smoke and curve B is silica dust. Circles represent points which determine slope of the curves; cross lines represent points, determined by stop watch, at which the respirators were tested.

between tests, the settling curve (Fig. 4) is determined. From this curve, the concentrations in terms of Tyndall effect can be interpolated for any desired time during the series of mask tests.

Effect of Leakage

In masks such as the Army model 1919, the Burrell dust mask, and our experimental cotton variety, the construction prevents leakage—the filters may not be highly efficient, but all the test suspension passes through the filters and none leaks around the edges. Therefore it is sufficient to test these filters without the gas mask headpiece and noncollapsible tubing by attaching the filters directly to the Tyndallmeter. The pig snout respirators often leak around the edge of the filters and through the expiration valves. In order to approximate the conditions under which the pig snout respirators are worn, we removed the inflatable rubber which fits around the respirator and against the face of the wearer. We then pulled one end of a large rubber tube over the respirator and attached the other end to the Tyndallmeter. In this way, our tests took into account whatever leakage there might be around the filter pads or through the expiration valves. In one pig snout respirator, sponge type, the expiration valve leaked so badly that it was necessary to block it off and test only the sponge and its holder. This test gave, therefore, the dust filtering power of the sponge, but not that of the entire respirator.

Where leakage of this sort occurs, or where the filters themselves permit perceptible amounts of the suspension to pass through—and both these defects are commonly found in industrial masks—we have found that the efficiency of the mask may vary with the rate of air flow. Dr. Sebastian (12) writes us of his experience, possibly with the more efficient type of mask used in chemical warfare: ". . . . we have found in our work that the efficiency [of a filter] is independent of the rate of flow. The per cent. penetration is always the same regardless of the rate of flow."

The extent to which leakage around the filters of the pig snout masks occurs is shown by a comparison of the filtering efficiencies of the pig snout respirators Nos. 1, 2, and 3 (Table 1) with those of the Burrell and cotton masks. The tobacco smoke efficiencies of the latter (Column IV) increased as the rate of air flow was decreased. In the three pig

snouts, the reverse was true. Moreover, the sponge respirators were apparently a little more effective wet than dry; and the cotton pad type (No. 3) seemed to work somewhat better dry than wet. This behavior of the pig snouts may have been due to the fact that either high rates of air flow or the wetting of the sponges in the sponge types caused the filters to squeeze up against the supporting frames of the respirators, thus reducing the leakage around the edges of the filter and decreasing the size of its voids. In the pig snout No. 4 (filter paper), the general construction and method of holding the filter were so successful that leakage was slight. In regard to the number of layers of filter paper recommended, the manufacturers advised using as many papers as the wearer can breathe through comfortably, and this is indeed the most practical direction since filter papers may differ very much in texture.

Although at present no pig snout respirators are equipped with any but small, cheap, replaceable filters, there is no reason why large, efficient filters of light weight cannot be substituted. Probably no improvement in the filters themselves, however, will be effective until some better method has been devised to prevent leakage around the edges.

After a mask has been tested for leakage through and around the filter, there still remains the possibility of leakage at the facepiece. As a final test of the entire mask, it is recommended that the mask be worn in an atmosphere containing a black, physiologically inert suspension like lamp black or powdered soft coal. If the mask is inefficient, traces of black in the nasal discharge or in the sputum of the wearer will soon be evident. Masks which protect against lamp black or powdered coal, both of which consist of very small particles, can be safely used against the dusts commonly encountered in industry.

Data on Comparative Tests

In Tables 1 and 2 are given the data from our tests on masks and respirators: the effective filtering areas, the rates of air flow at which the tests were made, the initial resistances, Tyndallmeter efficiencies, and the effect of plugging with zinc oxide fume.

A comparison between the filtering efficiencies for zinc oxide and for tobacco smoke shows that the smoke test is the more rigorous of the two. The efficiency of our new experimental cotton masks (Table 1, Column IV) was only 22 per cent. against tobacco smoke; after treatment for seventy-five seconds with zinc oxide fume drawn through at 85 liters a minute, the efficiency rose to over 97 per cent. against zinc oxide. The same mask was then tested immediately against tobacco smoke and caught only 66 per cent. (Table 2, Column I). It was then plugged for fifty-four minutes with zinc oxide fume (Table 2, Columns III and IV) and the tobacco smoke efficiency rose to 93 per cent., which seemed to be about the maximum attainable with the fabric we used.

Both cotton and Burrell masks were tested against tobacco smoke before plugging with zinc oxide, immediately after plugging, and then

TABLE 1.—FILTERING EFFICIENCIES AND RESISTANCES OF MASKS AND RESPIRATORS WHEN NEW[1]

Type of Mask	I Effective Filtering Area	II Air Flow	III Resistance	Tyndall Efficiency against IV Tobacco Smoke	Tyndall Efficiency against V Silica
	sq. cm.	*l. per min.*	*mm. H_2O*	%	%
Filter of U. S. Army model 1919	460	85	36	>97	>97
		70	30	>97	
		50	21	>97	>97
Burrell	840	85	7.6	82	>97
		70	5.8	85	
		50	3.8	88	>97
Experimental cotton	1,290	85	2.7	22	69
		70	1.9	25	
		50	1.1	31	71
Pig snout #1					
Sponge wet	?	85	37	41	97
		50	18	15	92
Sponge dry		85	23	31	89
		50	13	15	72
Pig snout #2					
Sponge wet	?	85	5.8	10	76
		50	3.0	7	64
Sponge dry		85	5.3	3	67
		50	2.5	3	49
Pig snout #3					
Pad wet	20	85	56	44	>97
		50	28	39	96
Pad dry		85	30	53	>97
		50	18	39	92
Pig snout #4					
Filter paper 2 papers	45	85	6.9	5	86
		50	3.0	5	62
Filter paper 4 papers		85	10.2	7	97
		50	4.7	13	88
Filter paper 6 papers		85	9.7	8	94
		50	4.6	14	89

[1] Silica tests on pig snouts are approximate as it was impossible to prevent plugging and rapid increase in efficiency.

fter standing in room air for a number of days. The average final tobacco smoke efficiencies in all cases were a little below those obtained immediately after plugging, indicating that the filtering efficiency of the oxide coating may change somewhat on standing.

efficiency in order to show no traces of zinc oxide by precipitator.

TABLE 2.—EFFECT OF PLUGGING WITH ZINC OXIDE ON EFFICIENCIES AND RESISTANCES OF MASKS AND RESPIRATORS

Type of Mask	Tobacco Smoke Efficiencies			Increase in Resistance Caused by ZnO Plugging at 85 L. per Min. for		
	I Plugged until No ZnO Passed through by Tyndallmeter	II Plugged until No ZnO Passed through by Precipitator	III Plugged 54 Minutes	IV 54 Minutes	V 7.4 Minutes	VI 24 Minutes
	%	%	%	*mm. H_2O*	*mm. H_2O*	*mm. H_2O*
U. S. Army model 1919, normal size	>97	>97	>97	75	.....	36[1]
U. S. Army model 1919, half size	....	....	....	....	.....	178[1]
Burrell, normal size	91	95	>97	28	3.4[2]	25[1]
Burrell, half size	....	....	....	....	.....	235[1]
Experimental cotton	66	92	93	13	5.8[2]	....
Pig snout #3	....	....	....	....	292[3] 174 (50 l. per min.)	....

[1] Both U. S. Army masks were plugged at the same time, and both Burrell masks.
[2] Cotton mask usually has lower resistance than Burrell.
[3] Estimated.

Table 2 (Columns I and II) gives an approximate idea of the sensitivity of tests by Tyndallmeter and by electric precipitator. An experimental cotton mask which gave no Tyndall reading on zinc oxide showed by electric precipitator that traces of zinc oxide passed through, and the masks had to be plugged (with zinc oxide) to a 92 per cent. tobacco smoke

Figure 5 shows the dust filtering efficiency of a pig snout cotton filter pad (not the entire respirator as ordinarily worn). One-half of the photograph represents the "bag dust" in the air entering the filter pad; the other half, the dust caught on a celluloid foil of an electric precipitator (18) after having been drawn through the filter pad. Both were made at the same time and under identical conditions. Samples from the same places on each of the two foils were fastened with amyl acetate to microscopic slides, mounted in dammar dissolved in xylol, sealed

with a cover slip, and 250 particles on each slide measured with a filar micrometer, using a $\frac{1}{12}$-inch oil im-

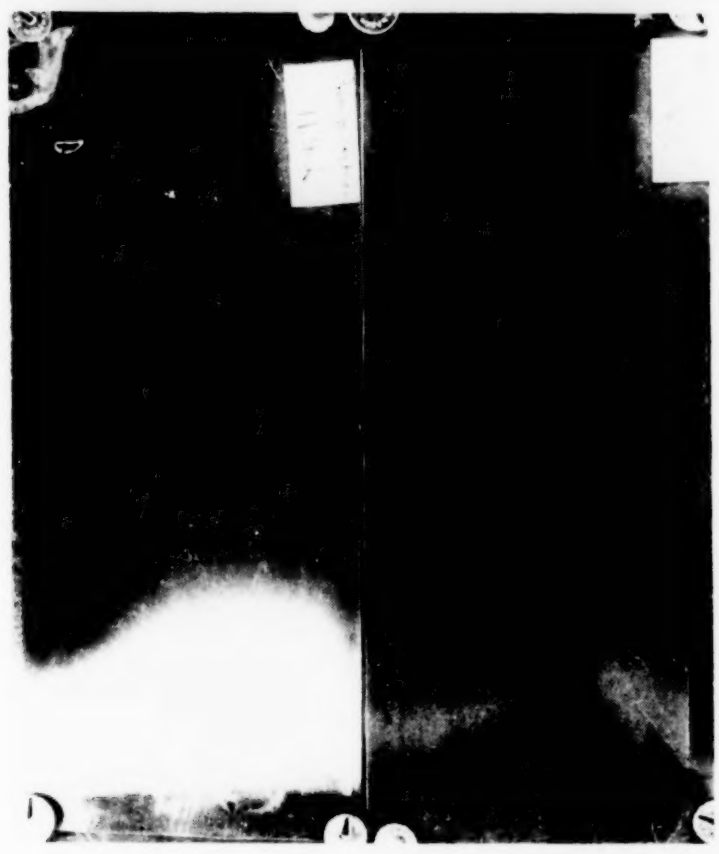

FIG. 5.—Precipitates of "bag dust" (see Fig. 6) caught on the celluloid foil of an electric precipitator (3) (18). Foil on left represents dust in air; foil on right, dust which passed through respirator pad. Samples were taken simultaneously at the same rates.

mersion objective. The resulting size-frequency relations are plotted in Figure 6. They indicate that the filtered dust is distinctly more uniform than the unfiltered and that the median size of the filtered is smaller than that of the unfiltered. After the dust suspensions had remained in the air for some time, however, different results were obtained. The large particles had settled out and, when samples of the filtered and unfiltered dusts were examined under the microscope, it was difficult to distinguish between the two.

RESISTANCE TO BREATHING AND THE FILTERING AREA

In the industrial mask specifications issued by the Bureau of Mines (19), two types of masks described

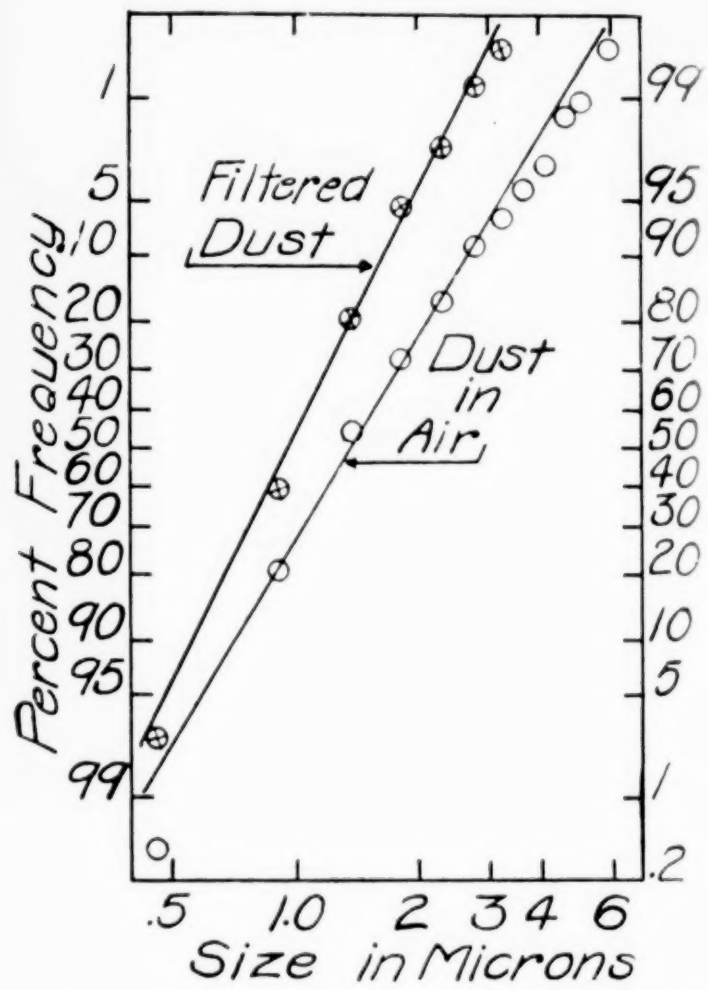

FIG. 6.—Size-frequencies of dust particles in respirator tests, 250 particles measured for each curve. The filtered dust gives smaller and more uniform particles than the unfiltered.

are of interest to us: (*a*) those required to show at least 50 per cent. filtering efficiency against tobacco smoke, and (*b*) those required to show 95 per cent. efficiency. In addition to the filtering tests, the Bureau requires "man tests" in which the masks are worn for twenty minutes in atmospheres containing suspensions of material against which they are intended to protect the wearer. Dur-

ing these exposures, the subjects perform light or vigorous physical labor. The masks are tested for resistance to breathing both before and after the filtering and man tests. The resistance must not exceed 102 mm. (4 inches) of water pressure when measured at an air flow of 85 liters a minute. In spite of the fact that it was Fieldner (7) of the Bureau of Mines who suggested the advisability of using large filtering areas to prevent plugging and increase of resistance, we believe that the Bureau's present specifications (19) do not emphasize this point enough. A man test of twenty minutes, even with 500 parts per million of tin tetrachloride in the air, seems to us too short to show whether or not plugging will be an important factor.

The rate at which the resistance of a given filter increases owing to plugging depends on (*a*) the nature, and (*b*) the concentration of the suspension, (*c*) the rate at which the air is drawn through the masks, as well as (*d*) the texture, (*e*) the density, and (*f*) the area of the filter. In practical work, the last three factors, (*d*), (*e*), and (*f*), are under control; the first three, (*a*), (*b*), and (*c*), must be taken as they occur.

Table 2 (Columns IV, V, and VI) shows the rates at which masks and respirators with different filters of various areas increase in resistance when plugged with zinc oxide fume. The results of three tests are given: one (Column IV) in which fume was drawn simultaneously through the Army, Burrell, and cotton masks at 85 liters a minute for fifty-four minutes; a second (Column V) in which the Burrell, cotton, and pig snout (cotton pad filter) masks were plugged; and a third (Column VI) in which the normal and half-sized[7] Army and Burrell filters were compared.

The tests the results of which are listed in Column VI show the effect of filtering area on the increase in resistance caused by plugging with zinc oxide. Two separate tests, each of twenty-four minutes, were made. In the first, the normal and half-sized Burrell were treated; and in the second, the normal and half-sized Army mask. The resistances were measured immediately before and after the tests, and the rate of air flow was kept constant at 85 liters a minute. The concentrations of zinc oxide used varied from approximately 500 to 300 mg. per cubic meter—concentrations which are severe, but which are substantially lower than some we have breathed ourselves in experimental work and some we have encountered in industry. In both pairs of tests, the concentration decreased uniformly but noticeably as each test progressed.

These tests show the importance of large filtering areas. In normally clean air, doubling the area reduces the resistance by a little less than one-half (the relation between resistance and area is usually not linear). In air containing appreciable amounts of freshly formed fume, our results indicate that doubling the area may reduce the tendency to plug by as much as three-fourths.

Summary

Masks for protection against dust and fume particles must be provided

[7] One-half of the filter was blocked off.

with effective filters, preferably of a fibrous nature and with large cross-sectional area. The materials used in gas masks for protection against toxic gases are ineffective in removing particles of dusts and fumes.

The masks (filters) described and tested include (*a*) the United States Army model 1919; (*b*) pig snout respirators with filters of sponges, cotton pads, or papers; (*c*) the Burrell dust mask; and (*d*) a mask of cotton fabric used industrially for the collection of zinc oxide. Various types of headpieces and accessory equipment are also discussed.

The suspensions used for testing the masks were (*a*) tobacco smoke (particles about 0.27 micron), (*b*) zinc oxide fume made by exploding zinc powder and potassium chlorate (particles about 0.5 micron), and (*c*) a mineral dust and a ground silica (particles whose median size were between 1 and 3 microns).

The respective tendencies of these suspensions to plug the filters through which they were drawn, thus increasing resistance to breathing and filtering efficiency, are discussed. Filtering efficiencies were determined by Tyndallmeter, a method sufficiently accurate for industrial masks, but not so sensitive as electric precipitation.

The efficiency of masks of large or small area can be very greatly increased by plugging the surface meshes with a freshly generated, finely divided fume like zinc, magnesium, or aluminium oxide. If the filtering area is small, plugging quickly increases the resistance to prohibitive figures; but masks with large area (800 to 1,200 sq. cm.) can be plugged to give perfect protection against finely divided lead fume and over 97 per cent. against tobacco smoke. At the same time, the resistance to air flow can be kept below 30 mm. of water pressure measured at 85 liters a minute.

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BOOK REVIEW

PUBLIC HEALTH LAW. A MANUAL OF LAW FOR SANITARIANS. By *James A. Tobey*, M.S., LL.B., Lecturer on Public Health Law at the Massachusetts Institute of Technology, Yale School of Medicine, and Columbia University; Member of the Bar of the District of Columbia and of the United States Supreme Court; Fellow, American Public Health Association. With a foreword by Charles V. Chapin, M.D., Sc.D. Cloth. Pp. xviii, 304 with appendixes and indexes. Baltimore: The Williams & Wilkins Co., 1926.

To those who depend on reference works in public health law, this book by Tobey will meet a real need. Between the standard work by Parker and Worthington (1892) and that by Hemenway (1914) there is a distinct field for this volume, addressed as it is to sanitarians and other interested persons who have no legal training. While stating concisely the fundamental legal principles applicable to public health procedure, this book also serves as an introduction to legal methods and as a source of pertinent legal references. As Dr. Chapin points out in his foreword, the information on court procedure included in the book is well designed to save much misunderstanding and annoyance and is invaluable to any new health officer. It should be read in connection with the author's new volume, "The National Government and Public Health," a publication of the Institute for Government Research.

In scope this book presents in systematic form the development of public health law in the United States and our peculiar relations between federal and state authority. The police power as it bears on administrative measures in state and local health departments is described and the procedures connected with school hygiene, vaccination, control of foods and drugs, control of communicable diseases, and control of nuisances are outlined in a fashion understandable to the nonlegal worker. Methods and principles of drafting health legislation and the procedures in law enforcement are well stated. The appended references and summaries of cases and legal health provisions are a distinctly useful feature of this valuable book.—*R. M. Atwater.*